

CLAIMS

What is claimed is:

1. A method of tuning a transducer circuit comprising the steps of:
identifying the transducer circuit having an ultrasonic transducer that includes at least one reactance characteristic and an operating frequency range, and at least one signal path that is electrically coupled to the ultrasonic transducer; and
inserting a balancing circuit into the at least one signal path to substantially balance the at least one reactance characteristic of the ultrasonic transducer over the operating frequency range.
2. The method of claim 1, wherein the at least one signal path includes one or more of a transmit signal path and a receive signal path.
3. The method of claim 2, wherein the at least one reactance characteristic includes a capacitance of the ultrasonic transducer.
4. The method of claim 3, wherein the balancing circuit is inserted into the receive signal path.
5. The method of claim 4, wherein the balancing circuit includes a negative capacitor circuit to substantially balance the capacitance of the ultrasonic transducer.
6. The method of claim 5, wherein the negative capacitor includes an op-amp and a plurality of feedback resistors.
7. The method of claim 5, wherein the negative capacitor includes a pair of transistors.
8. The method of claim 5, wherein the balancing circuit further includes a plurality of switches to isolate the balancing circuit from the ultrasonic transducer during a transmission.
9. The method of claim 8, wherein the plurality of switches include a plurality of transistors.

10. The method of claim 8, wherein the at least one reactance characteristic further includes a negative reactance of the ultrasonic transducer.
11. The method of claim 10, wherein the balancing circuit further includes an inductance for substantially balancing the negative reactance of the ultrasonic transducer over the frequency range, the inductance being inserted into the transmit signal path and isolated from the receive signal path during the transmission using the plurality of switches.
12. The method of claim 2, wherein:
 - the transmit signal path of the transducer circuit is electrically coupled to the ultrasonic transducer using a first electrode of the ultrasonic transducer; and
 - the receive signal path of the transducer circuit is electrically coupled to the ultrasonic transducer using a second electrode of the ultrasonic transducer.
13. The method of claim 12, wherein the first electrode is a high voltage signal path and the second electrode is a low voltage signal path.
14. The method of claim 13, wherein the balancing circuit includes a negative capacitor circuit that is inserted into the low voltage signal path for substantially balancing the at least one reactance characteristic.
15. The method of claim 14, wherein the balancing circuit further includes an inductance that is inserted into the high voltage signal path for further substantially balancing the at least one reactance characteristic.
16. A tuned transducer circuit comprising:
 - a electro-acoustic transducer circuit having an ultrasonic transducer that includes at least one reactance characteristic and an operating frequency range, and at least one signal path that is electrically coupled to the ultrasonic transducer; and
 - a balancing circuit that is inserted into the at least one signal path to substantially balance the at least one reactance characteristic of the ultrasonic transducer over the operating frequency range.

17. The circuit of claim 16, wherein the at least one signal path includes one or more of a transmit signal path and a receive signal path.
18. The circuit of claim 17, wherein the at least one reactance characteristic includes a capacitance of the ultrasonic transducer.
19. The circuit of claim 18, wherein the balancing circuit is inserted into the receive signal path.
20. The circuit of claim 19, wherein the balancing circuit includes a negative capacitor circuit to substantially balance the capacitance of the ultrasonic transducer.
21. The circuit of claim 20, wherein the negative capacitor includes an op-amp and a plurality of feedback resistors.
22. The circuit of claim 20, wherein the negative capacitor includes a pair of transistors.
23. The circuit of claim 20, wherein the balancing circuit further includes a plurality of switches to isolate the balancing circuit from the ultrasonic transducer during a transmission.
24. The circuit of claim 23, wherein the plurality of switches include a plurality of transistors.
25. The circuit of claim 23, wherein the at least one reactance characteristic further includes a negative reactance of the ultrasonic transducer.
26. The circuit of claim 21, wherein the balancing circuit further includes an inductance for substantially balancing the negative reactance of the ultrasonic transducer over the operating frequency range, the inductance being inserted into the transmit signal path and isolated from the receive signal path during the transmission using the plurality of switches.
27. The method of claim 17, wherein:
the transmit signal path of the transducer circuit is electrically coupled to the ultrasonic transducer using a first electrode of the ultrasonic transducer; and
the receive signal path of the transducer circuit is electrically coupled to the ultrasonic

transducer using a second electrode of the ultrasonic transducer.

28. The method of claim 27, wherein the first electrode is a high voltage signal path and the second electrode is a low voltage signal path.
29. The method of claim 28, wherein the balancing circuit includes a negative capacitor circuit that is inserted into the low voltage signal path for substantially balancing the at least one reactance characteristic.
30. The method of claim 29, wherein the balancing circuit further includes an inductance that is inserted into the high voltage signal path for further substantially balancing the at least one reactance characteristic.
31. A method of tuning a transducer circuit comprising the steps of:
 - identifying the transducer circuit having an ultrasonic transducer that includes a capacitance and an operating frequency range, and a receive signal path that is electrically coupled to the ultrasonic transducer;
 - inserting a negative capacitor into the receive signal path to substantially balance the capacitance of the ultrasonic transducer over the operating frequency range; and
 - isolating the negative capacitor from the ultrasonic transducer during a transmission of the transducer circuit using a plurality of switches.
32. The method of claim 31, wherein the ultrasonic transducer further includes a negative reactance and a transmit signal path, and the balancing circuit further includes an inductance for substantially balancing the negative reactance of the ultrasonic transducer over the operating frequency range, the inductance being inserted into the transmit signal path and isolated from the receive signal path during the transmission using the plurality of switches.
33. A tuned transducer circuit comprising:
 - a transducer circuit having an ultrasonic transducer that includes a capacitance and an operating frequency range, and a receive signal path that is electrically coupled to the ultrasonic transducer;
 - a negative capacitor inserted into the receive signal path to substantially balance the

capacitance of the ultrasonic transducer over the operating frequency range; and
a plurality of switches that isolate the negative capacitor from the ultrasonic transducer
during a transmission of the transducer circuit.

34. The circuit of claim 33, wherein the ultrasonic transducer further includes a negative reactance and a transmit signal path, and the balancing circuit further includes an inductance for substantially balancing the negative reactance of the ultrasonic transducer over the operating frequency range, the inductance being inserted into the transmit signal path and isolated from the receive signal path during the transmission using the plurality of switches.

35. A method of tuning a transducer circuit comprising the steps of:
identifying the transducer circuit having a plurality of ultrasonic transducers, each
ultrasonic transducer including a capacitance and an operating frequency range, and
one or more receive signal paths that are electrically coupled to the plurality of
ultrasonic transducers; and
inserting a balancing circuit into the one or more receive signal paths to substantially
balance the capacitance of each ultrasonic transducer over the operating frequency
range.

36. The method of claim 35, wherein the balancing circuit is a negative capacitor.

37. The method of claim 35, further comprising the step of isolating the balancing circuit
from the plurality of ultrasonic transducers during a transmission of the transducer circuit using a
plurality of switches.

38. The method of claim 37, wherein each ultrasonic transducer further includes a negative
reactance and one or more transmit signal paths, and the balancing circuit further includes an
inductance for substantially balancing the negative reactance of the ultrasonic transducer over the
operating frequency range, the inductance being inserted into the one or more transmit signal
paths and isolated from the one or more receive signal paths during the transmission using the
plurality of switches.

39. A tuned transducer circuit comprising:

a transducer circuit having a plurality of ultrasonic transducers, each ultrasonic transducer including a capacitance and an operating frequency range, and one or more receive signal paths that are electrically coupled to the plurality of ultrasonic transducers; and a balancing circuit inserted into the one or more receive signal paths to substantially balance the capacitance of each ultrasonic transducer over the operating frequency range.

40. The circuit of claim 39, wherein the balancing circuit is a negative capacitor.

41. The circuit of claim 39, further comprising a plurality of switches that isolate the balancing circuit from the plurality of ultrasonic transducers during a transmission of the transducer circuit.

42. The circuit of claim 41, wherein each ultrasonic transducer further includes a negative reactance and one or more transmit signal paths, and the balancing circuit further includes an inductance for substantially balancing the negative reactance of the ultrasonic transducer over the operating frequency range, the inductance being inserted into the one or more transmit signal paths and isolated from the one or more receive signal paths during the transmission using the plurality of switches.